PROC. R. SOC. VICT. vol. 94, no. 4, 173-181, December 1982

THE GEOLOGY OF CAPE EVERARD, VICTORIA

By MARGARET C. FRY AND C. J. L. WILSON

Department of Geology, University of Melbourne, Parkville, Victoria 3052

ABSTRACT: The Ordovician sediments of Cape Everard constitute a sequence of sandstones, greywackes and siltstones interbedded with minor black shales. Four lithofacies are recognized and are interpreted as proximal turbidites, thought to be deposited by turbidity currents. The association of lithofacies suggests that sedimentation occurred on and around the upper mid-fan region of a submarine fan system. Palaeocurrent indicators suggest turbidity current transport in a northerly direction. The strata are folded into tight folds and have undergone low grade regional metamorphism, with little disruption of the original sedimentary texture. These sediments are intruded by granite with insignificant contact metamorphic effects and are overlain by a possibly Miocene calcarenite.

Cape Everard, which includes Point Hicks, is a granite headland 40 km southeast of Cann River township in East Gippsland (Fig. 1). Exposure is limited to shore platforms and cliffs as most of the Cape and adjacent areas are covered by a complex of Holocene transgressive dunes superimposed on older (Pleistocene) sand ridges (Rosengren 1978). The granite is considered by Douglas (1974) to be a small outlier of the Early Devonian Bega Batholith (396 ± 16 Ma, K/Ar; Richards & Singleton 1981) and intrudes folded Ordovician sedimentary rocks. Unconformably overlying the granite are restricted calcarenite deposits and the granite is intruded by three olivine bearing basaltic dykes (1 m wide).

The best exposures of the Ordovician are found on the shore between the mouths of the Thurra and Mueller Rivers, in areas 1 and 2 (Fig. 1). Here a 200 m thick succession of turbidites crops out and is comprised of three main lithologies namely: coarse sandstone, siltstone and shale. Minor chert (≤2 m thick) has been found with comparable rocks in the Thurra River. All these rocks bear the weak imprint of lower greenschist facies regional metamorphism and have near vertical dips (Fig. 2) and one generation of upright isoclinal folds which plunge 15° towards 356°. Faults with unknown displacements parallel the N-S trending bedding and are only recognised by comparison of sedimentary cross-sections; these are considered to be bedding plane thrusts and are similar to those described by Wilson *et al.* (1982). Other vertical faults, often accompanied by quartz veins, trend to the northwest (Fig. 2). They appear to be later features and are accompanied by minor crenulation cleavage.

These Ordovician sediments are similar to the Mallacoota Beds described by Fenton *et al.* (1982), which are of Late Ordovician age on the basis of graptolites found at Seal Creek (P. de Hedouville, unpublished data, April 1982). A conodont fauna (I. Stewart *in* Webby *et al.* 1981, p. 30) obtained from a silcified shale unit in a road cutting on the north side of the Thurra River bridge at Cape Everard, also suggests a Late Ordovician age. The sediments at Cape Everard are coarser grained and not as well-laminated as the Mallacoota succession. It is therefore the primary purpose of this paper to describe the sediments and determine the environment of deposition and compare it with the Mallacoota sequence. At the same time, the other rock types recognised in the area will be briefly described. Data were collected following the methods used in Fenton *et al.* (1982) and Wilson *et al.* (1982) and further details may be found in Fry (1981).

ORDOVICIAN SEDIMENT PETROGRAPHY

The sequence is characterised by thick-bedded and coarse-grained deposits that are comparable to those described by Walker and Mutti (1973). The turbidites show numerous sedimentary structures and different combinations of the divisions of Bouma (1962). Measured sections illustrating the sedimentary features in areas 1 and 2 are shown in Fig. 3. Sections 9A and 9B are situated on adjacent limbs of a fold. Younging evidence in Sections 14 and 15 suggests that a fold lies between them, but the lithology, thickness and sedimentary structures do not correlate. This is interpreted as being due to a bedding-plane thrust sub-parallel to the axial-surface of a tight-fold.

Three main lithologies are distinguished in the rocks at Cape Everard.

Sandstone and greywackes are mainly clast-supported with clay matrix contents of <5 to 20%. Greywackes (with more than 10% matrix) only comprise about 25% of this lithology. Quartz with undulose extinction comprises 95-100% of the framework grains, whereas metamorphic quartz displaying re-crystallization is restricted to coarse sandstone and "coarse clasts". Grains are subangular to rounded (Fig. 4) and size (<1 mm-4.0 mm) varies within individual beds and between beds. Plagioclase is present as rare grains. The matrix is composed of muscovite (<2 mm), partly recrystallized and deformed during the regional metamorphism. The accessory minerals are hornblende, zircon, tourmaline and iron oxide. Intraclasts of shale and mud are common.

Bodies interpreted as concretionary features, postdate sedimentation but predate deformation and are comparable to similar features that are folded and metamorphosed in other areas in East Gippsland (e.g. Eaton 1980). They occur at different intervals within some coarse sandstone beds as zones up to 8 cm thick that show slight colour variation and sometimes have the appearance of distinct units. These coarse layers lack

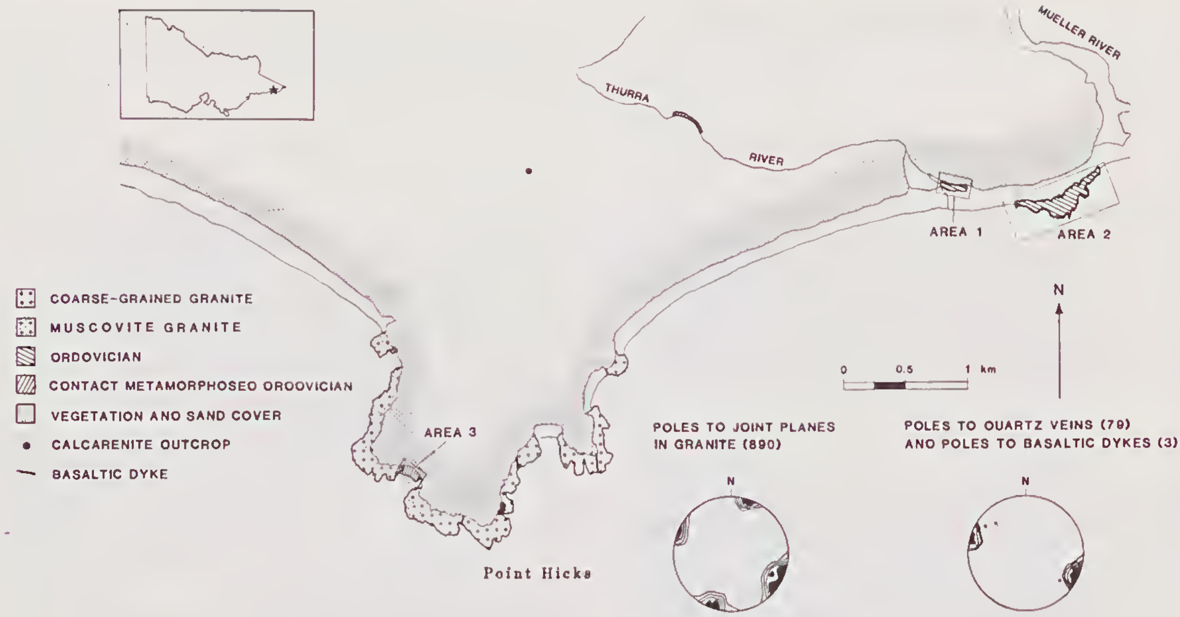

FIG. 1—Map of Cape Everard area showing location of major rock types and areas 1, 2, and 3 detailed in Fig. 2. The contoured data are poles to joints and quartz veins in the granitoid rocks, and contours are ≥1% per 1% area, ≥5% per 1% area, ≥10% per 1% area and ≥20% per 1% area.

clear fining-upwards grading and are discontinuous along their length (1-4 m) with rounded terminations. There are no obvious compositional differences in the clastic sand-grain content between these layers and the adjacent sandstones, but the matrix of these bodies may contain a trace of calcite.

Siltstones are matrix supported (>35%) with quartz (<1 mm) and rare altered plagioclase. The matrix is composed of recrystallized muscovite and chlorite. Accessory minerals are the same as in the sandstones.

Shales are a minor component of the sediments at Cape Everard. They are grey to black and are similar to those described by Fenton *et al.* (1982). They are composed of quartz, muscovite and chlorite.

ORDOVICIAN SEDIMENT LITHOFACIES

Four major lithofacies crop out along the coast and are summarized below.

Massive sandstones

These are composed of coarse sands that fall within the A division of Bouma (1962) and comprise 13% of all beds. Individual sheets range from 1-100 cm thick with a median thickness of 40 cm, and are generally not laterally persistent for more than a few tens of metres of outcrop, with marked pinch and swell. Grading, when present, is usually confined to the top of the A division and may be the only internal sedimentary structure. The base may be either erosional or sharp (Fig. 5A) with rare flame structures (Fig. 5B). Amalgamation of the graded beds has resulted in apparently massive sand sequences more than 10 m thick, such as Sections 5, 6, and 7 (Fig. 3). Other sands occur as coarse-grained lens-like bodies ($<15\times60$ cm) that may show discontinuous coarse sandy layers up to 10 cm thick at the base.

Proximal turbidites

These comprise 57% of all beds and are composed of the AB, ABE and AE divisions of Bouma (1962). They consist predominantly of graded sandstone and siltstone, 5-35 cm thick (e.g. Sections 8, 9 and 10). Many fine sandstones and silt units have ripple cross-bedding or are slumped in the middle parts of thicker sand bodies (Fig. 5C and Sections 9B, 12, 13 in Fig. 3). There is also gradation between the two sets of structures. Coarse clasts (Fig. 5D) with lengths up to 12 cm, distributed in irregular fashion (in A division) or aligned with bedding (in B division) are particularly noticeable in Sections 4, 5 and 6 (Fig. 3).

Clasts of shale that range in length from 0.5-30 cm also occur in the A and B divisions of the more sandy units (see Sections 1 and 2 in Fig. 3). They appear to be rip-up clasts and occur in beds with an abundance of coarse sandstone clasts, suggesting an erosional history.

Distal turbidites

Where the lowest division of a bed is B, combinations of the Bouma sequences such as BCDE, BCE, CE and DE comprise 18% of all beds. They range in bed thickness from 1 to 100 cm with a median of 16 cm and have most of the features described by Fenton *et al.* (1982). Also common in the C division of these sediments is the occurrence of both coarse-grained clasts and shale clasts (Fig. 5E). The clasts are finer and smaller than those observed in the proximal turbidites and reveal internal folding and are enclosed in a bed that displays complete irregularity, except where micaceous

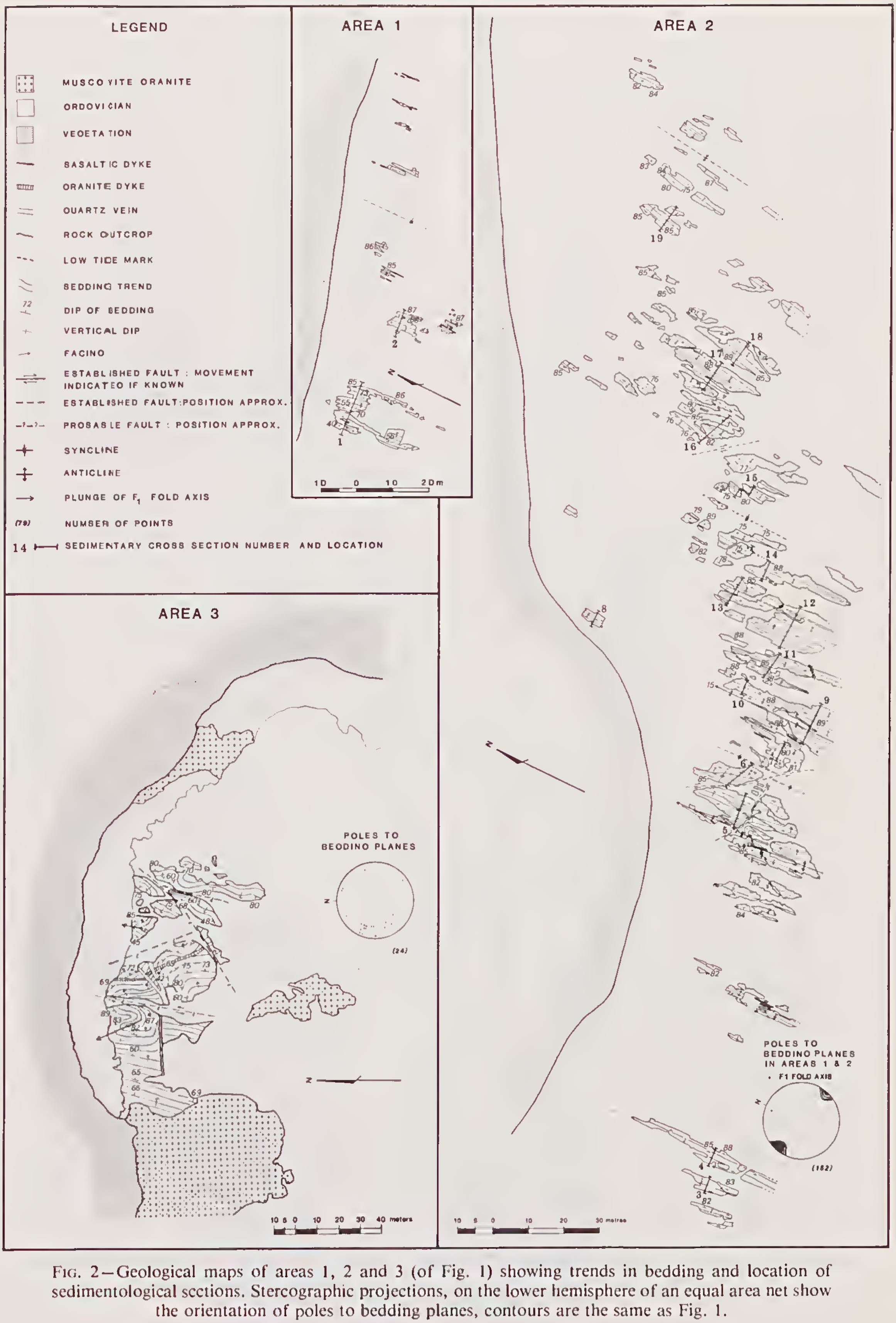

Fig. 2—Geological maps of areas 1, 2 and 3 (of Fig. 1) showing trends in bedding and location of sedimentological sections. Stereographic projections, on the lower hemisphere of an equal area net show the orientation of poles to bedding planes, contours are the same as Fig. 1.

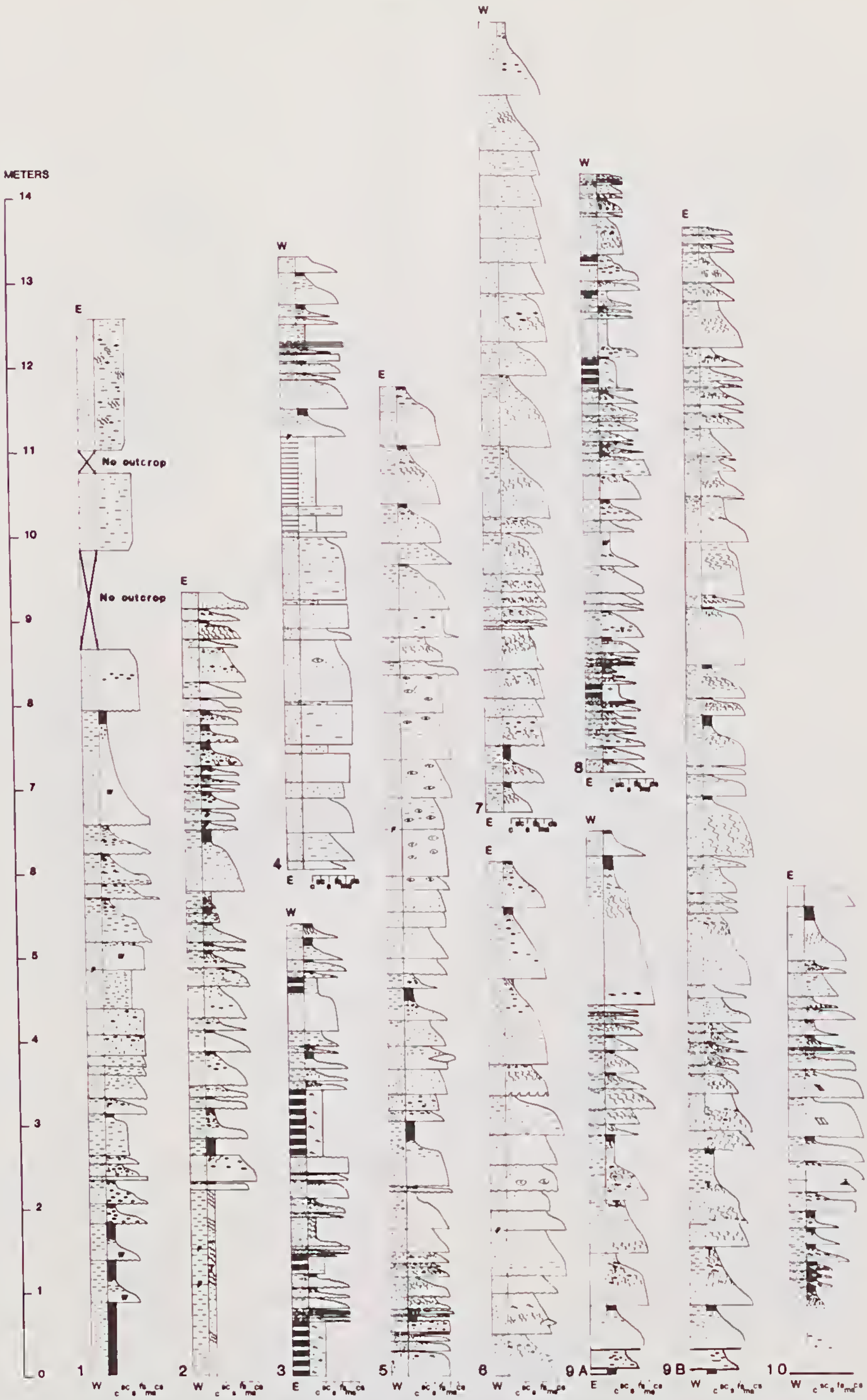

FIG. 3—Measured sections of the Cape Everard Ordovician sequence in areas 1 and 2. Locations of the sections are shown in Fig. 2.

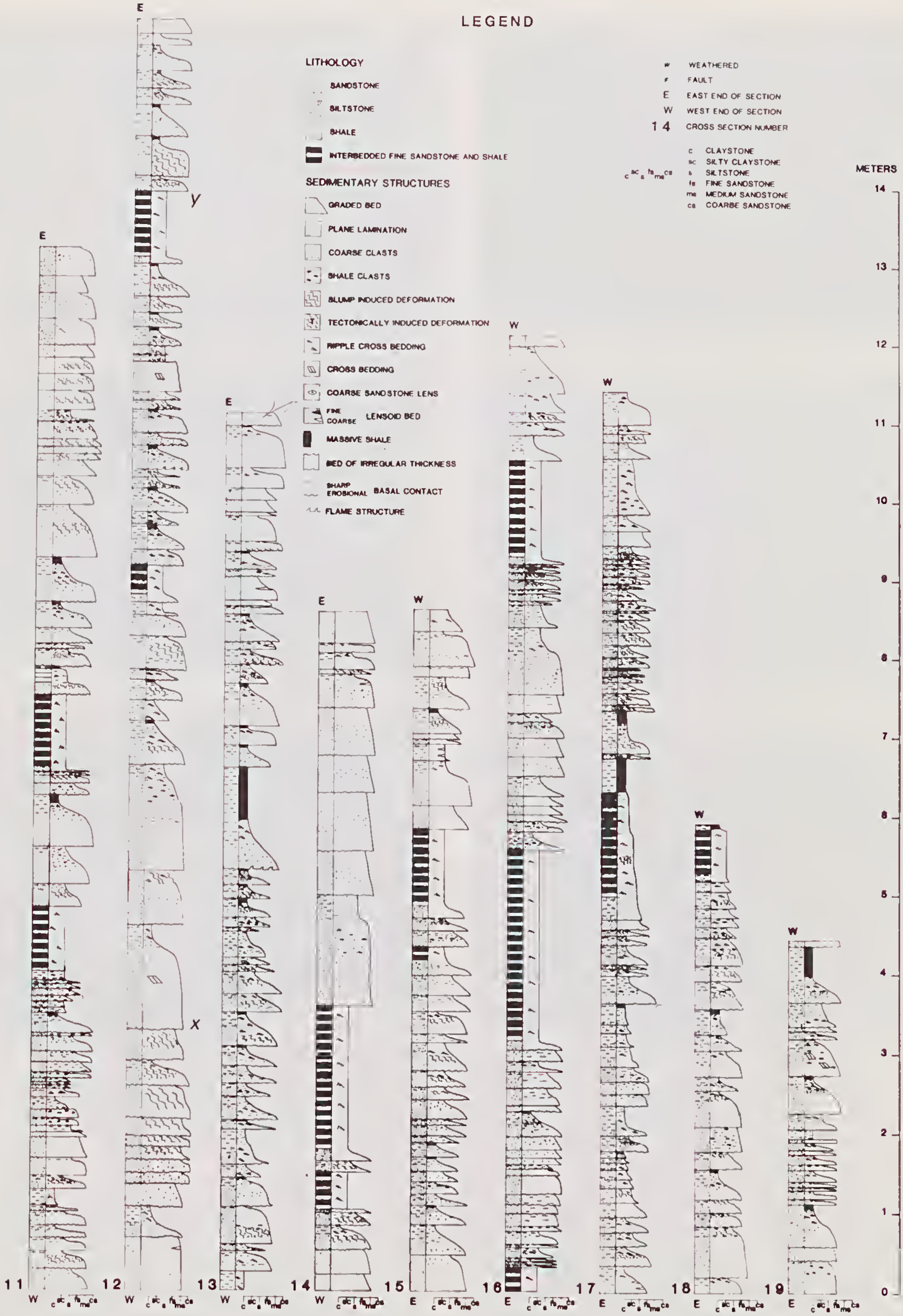

Fig. 3 (*continued*)

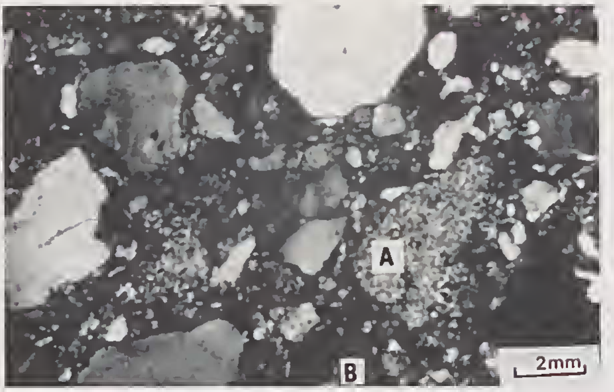

FIG. 4 — Photomicrograph illustrating coarse sandstone texture in Melbourne University Geology Department sample R27859. A recrystallised quartz grain is seen at A and a rare feldspar grain at B.

minerals and shale clasts are folded around the coarse sand clasts (Fig. 6). It is suggested that some C division clasts are remnant bedding clasts disrupted by slumping whereas the others, particularly the smaller ones, may represent shale introduced with the sediment load.

Thin sandstone beds interbedded with shale

These units make up 11% of all beds and occur as sequences between 0.8-2 m thick. The presence of cross bedding and ripple cross bedding in the fine sandstones indicates a Bouma C division with the seemingly massive overlying shale characteristic of E division. The abrupt change (Fig. 5F) between the two divisions could be interpreted as showing a change to pelagic deposition and the E division would be expected to show no internal grading or sedimentary features. It is on this basis that Fenton *et al.* (1982) suggested the fine sandstones were reworked by intermittent bottom currents, with subsequent slow deposition of a pelagite layer. However, close examination revealed overall grading and ripple cross bedding within each unit, suggesting that the beds are fine-grained tail deposits of individual turbidite events.

ENVIRONMENT OF DEPOSITION

In the Ordovician sediments of Cape Everard there is a preponderance of coarse sandstones which represent beds deposited in a high flow regime. Sand deposition was interrupted now and then by accumulations of silt and mud (under normal deep marine conditions) which form intercalations of siltstone and shale in a sequence composed predominantly of sand. These changes could be accounted for in terms of modern facies interpretation (Walker 1978) as deposits near or within a rapidly changing suprafan region.

Repetition of massive and graded sandstones (Sections 4, 5 and 6) with large lenses of coarse material (e.g. Section 12) suggests channel fill or overbank deposits in the upper or mid-fan region (Walker 1978). Coarse sand and shale clasts in the Bouma A and B divisions also suggest rapid erosion with short transport distance. Such an origin also explains some of the clasts recognised in C division whereas others may be remnants in slump beds. Fining upward sequences are restricted but are seen in Sections 12 (between X and Y), 18 and 19. These are repeating beds of diminishing size which Walker and Mutti (1973) interpret as a sequence formed in a prograding sumbarine fan. However, we favour the interpretation of Fenton *et al.* (1982) that at Cape Everard and Mallacoota these sequences are part of a channelled suprafan deposit and indicate proximity to the channel. The interbedded siltstones and shale with graded CE Bouma divisions suggest that these are fine tail deposits of individual turbidite events rather than regular reworking of the sands by intermittent bottom currents as proposed by Fenton *et al.* (1982) for similar rocks at Mallacoota. Similarly as these interbedded siltstones and shales are generally grouped together (e.g. Sections 3, 11, 12 and 14 to 18) as packets of distal turbidites, they may be interpreted as deposits derived from more than one channel (M. W. Fenton pers. comm.).

The initial dips of C-division cross-bed lamellae range from 15° to 25° and have been used as indicators of directions of sediment transport. They show a northerly current direction (Fig. 7) which is in agreement with measurements on similar rocks by Fenton *et al.* (1982) and Cas *et al.* (1980). The use of underlying scour or tool-marked surfaces was not possible as all exposed surfaces were essentially two-dimensional.

There is good correlation of individual graded beds near the fold hinge in Sections 9A and 9B, but as distance from the hinge increases the correlation decreases. This lateral change would be a response to the changing environment induced by the flow and position within the channelled suprafan region.

Two isolated contact metamorphosed cherts crop out in the Thurra River but their relation to the sedimentary sequence described here is unclear. Such cherts may be deposited in regions free of turbidity flow due either to topographic highs (channel levees) or to channel movement away from the area (Fenton *et al.* 1982). This lends support to the idea that the Cape Everard sequence is part of an extensive deposit formed on a rapidly changing channelled suprafan.

A lower mid-fan depositional environment has been favoured by Fenton *et al.* (1982) for the Mallacoota Beds at Mallacoota. However at Cape Everard there is strong evidence for channelled lithofacies that suggests an upper mid-fan. Distal outer fan and basin plain associations and proximal inner fan, slope and shelf associations are absent. A possible explanation for this is that the Ordovician in this part of Victoria was not a sedimentary wedge built off a prograding continental margin, instead it was a deeper water, channelled suprafan deposit (Walker & Mutti 1973). The detritus would be in part supplied from older fan sediments that were made available for redeposition by contemporaneous tectonism or sedimentary subsidence. Such an interpretation would explain the occurrence of sandstone and shale clasts within the coarse sandstone units. The intralayer slumps in the finer sandy units apparently

FIG. 5—A, coarse sandstone lens with sharp base and without grading, resting on a thin E division shale and C division in section 5. B, flame structure in a coarse A division in a massive sandstone in section 13. C, slumped sandstone-siltstone unit in section 13. D, irregular coarse clasts in an A division in Section 5. The clasts are grain supported with grain sizes greater than the surrounding sand. E, shale clasts composed of clay and phyllosilicate plates in a C division in section 18. F, intercalation of shale and siltstone in section 16.

indicate minor slope failure or may have resulted from impact of large gravity flows that crevassed the graded sandstone-siltstone facies. The source-rocks for the sequence are probably, as previously proposed (Fenton *et al.* 1982), the Cambrian and Precambrian sediments of the Ross Orogen of eastern Antarctica (Tessensohn *et al.* 1981).

METAMORPHOSED ORDOVICIAN

Limited outcrops of contact metamorphosed sediments can be seen in the Thurra River and as pods isolated by the granites, for example in area 3 (Fig. 2). They are sandy units that have been transformed to quartzites with large recrystallized muscovite. Minor shale intercalations contain spots of chlorite, muscovite,

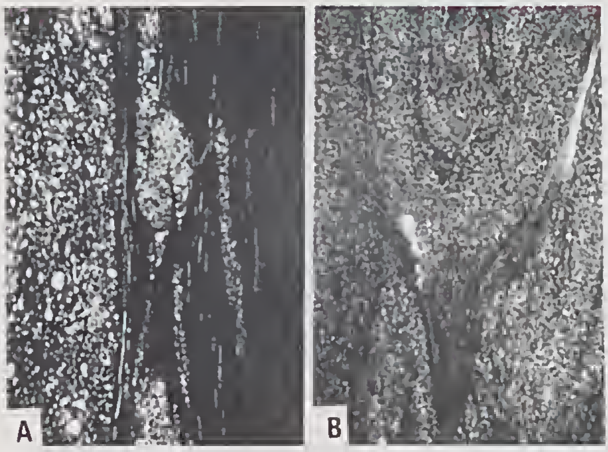

FIG. 6—Photomicrographs illustrating structures associated with sandstone and shale clasts (a) slump between siltstone and shale unit in Melbourne University Geology Department sample R27873; (b) bedding being folded adjacent to a sandstone clast in Melbourne University Geology Department sample R27863. Width of both micrographs are 4 mm.

quartz and opaques. The sediments have retained their folded pattern but display some localised refolding (area 3, Fig. 2).

GRANITOID ROCKS

Two distinct granites, crop out around the Point Hicks headland (Fig. 1). One is a muscovite bearing granite (average grain size 1 mm), found close to the Ordovician sediments; the other is a coarse-grained granite (up to 10 mm) with euhedral orthoclase phenocrysts (up to 20 mm). Both granites exhibit a hypidiomorphic-granular texture and are granites according to the I.U.G.S. classification with the modal compositions shown in Table 1. The boundary between the two types appears to be gradational. The more leucocratic, coarse-grained granite contains patches of idiomorphic tourmaline (1 to 10 cm) intergrown with the groundmass phase, especially near the boundary with the muscovite granite. A late-stage magmatic origin is favoured for much of the tourmaline as it rarely exhibits replacement textures.

Jointing is intense within all the granitoids with an average spacing of 1 m (Fig. 8). Their orientation (Fig. 1) corresponds to the regional trend of S_2 structures recognised in the Mallacoota region (Wilson *et al.* 1982) and this may reflect the stress field and deformation events occurring during the cooling of the granite. The joints occur in zones up to 30 m wide, particularly in the muscovite bearing granite, with more closely spaced joints (1 to 8 cm) that are often associated with quartz veins (2 mm to 3 cm). Thicker quartz veins are less common, but are found in the muscovite granite and contain pyrite, sphalerite and chalcopyrite.

TABLE 1
MODAL AND TEXTURAL VARIATION OF POINT HICKS GRANITOID ROCKS

Mineral	coarse-grained granite	muscovite-bearing granite
quartz	20	25
K-feldspar	50	50
plagioclase	10	5
biotite	15	5
muscovite	5	15
hornblende	Tr	Tr

accessories: zircon, tourmaline, sericite and apatite

MIOCENE CALCARENITE

East of the Point Hicks lighthouse the granite is overlain by a 3 m thick, cross-bedded calcarenite in which the foresets dip 33° towards 036°. The calcarenite contains calcareous clasts in a calcite matrix with less abundant well sorted and subrounded clasts of fine quartz. The biogenic fraction containing fragments of brachiopods, molluscs, forams, and bryozoans and, is unsorted. An isolated exposure of a similar rock also occurs 3 km to the north in the Pleistocene dunes (Fig. 1). This calcarenite is comparable to the Late Miocene "Bairnsdale Limestone" described in other parts of East Gippsland by Mallett (1977) and Parker (1979) and may represent a shallow water intertidal or beach deposit.

CONCLUSIONS

Deformation has not modified the sedimentary features in the Late Ordovician turbidite sequence, recognized at Cape Everard. Sedimentary structures and lithofacies suggest that:

1, the sequence is dominated by interbedded packets of sandy sediments (channels) with minor finer-grained,

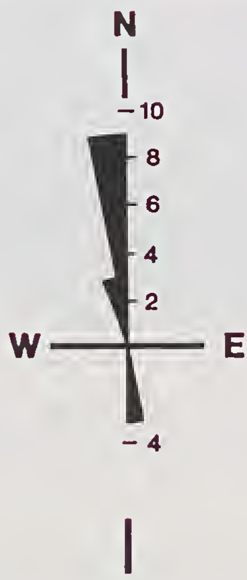

FIG. 7—Palaeocurrent directions using 10° intervals. Measurement taken from C-division ripple cross-bedding; 38 measurements taken from different beds occurring in all sections, except in sections 2 and 9.

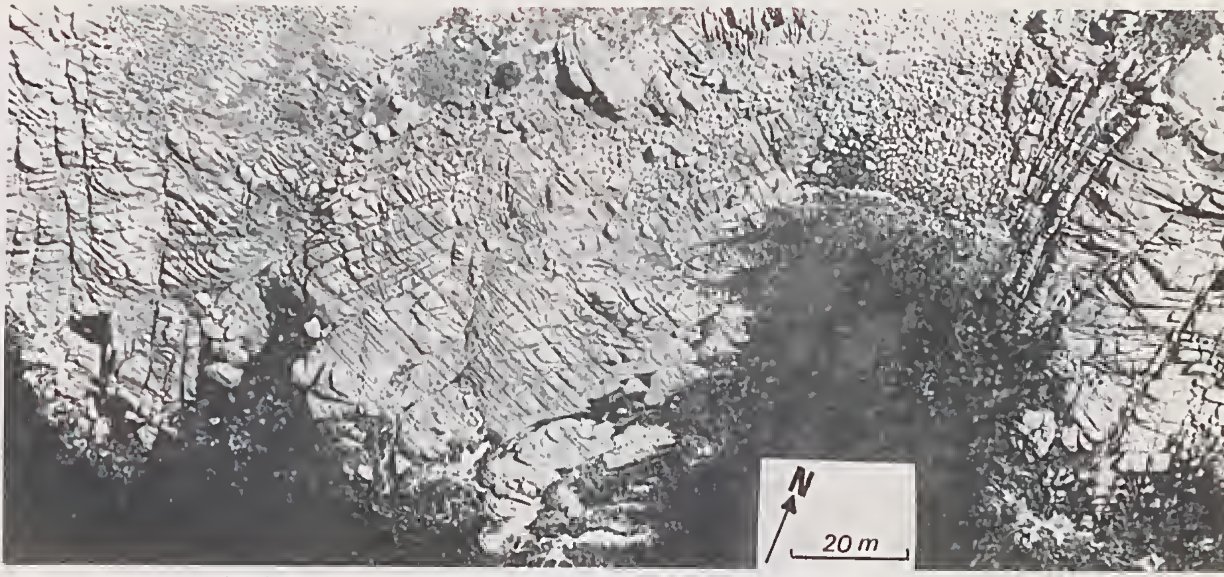

FIG. 8 — Aerial view illustrating N-S and E-W joint sets in the coarse-grained granite adjacent to the Point Hicks lighthouse.

thin-bedded muddy sediments (thinner bedded channel levee or fan fringe deposits).

2, individual sand units were deposited by north flowing currents in a rapidly changing channelled suprafan.

3, coarse sandstone and shale clasts are directly related to the flow regime of the turbidity current, being deposited in or near channels on the channelled suprafan. Irregular clasts occur in the Bouma A divisions and a laminated distribution is observed in the B divisions. Clasts in the C division are either introduced or more commonly remnant bedding resulting from slumping of the deposited sediments.

A coarse-grained granite with a less orthoclase- and more muscovite-rich western margin intrudes the Ordovician sediments at Point Hicks. Minimal contact metamorphic effects are observed because of paucity of outcrop and the quartz-rich nature of the adjacent sediments. Overlying the granite is a calcarenite deposited during a Miocene marine transgression.

ACKNOWLEDGEMENTS

We wish to thank the National Parks Service for giving us permission to work at Cape Everard and Transport Australia (Victoria region) for admittance to the lighthouse reserve at Point Hicks. Dr. J. B. Keene is thanked for his discussions about the sedimentology of the region and M. W. Fenton is thanked for his comments on the manuscript. D. D. Campbell is thanked for assistance with the drafting.

REFERENCES

BOUMA, A. H., 1962. *Sedimentology of some flysch deposits. A graphic approach to facies interpretation.* Elsevier, Amsterdam, 168p.

DOUGLAS, J. G., 1974. Explanatory notes on the Mallacoota 1:250 000 geological map. *Rept. geol. Surv. Vict.* 1974/6; 1-48.

EATON, P. C., 1980. The geology of Cape Conran, East Gippsland. BSc (Hons) Thesis, Univ. Melb. (unpubl.).

FENTON, M. W., KEENE, J. B. & WILSON, C. J. L., 1982. The sedimentology and environment of the Mallacoota Beds, Eastern Victoria. *J. geol. Soc. Aust.* 29: 107-114.

FRY, M. C., 1981. The geology of Point Hicks, Croajingolong, Victoria. BSc (Hons) Thesis, Univ. Melb. (unpubl.).

MALLETT, C. W., 1977. Tertiary foraminifera. PhD Thesis, Univ. Melb. (unpubl.).

PARKER, W. A., 1979. The Bairnsdale Limestone. BSc (Hons), Univ. Melb. (unpubl.).

RICHARDS, J. R. & SINGLETON, O. P., 1981. Palaeozoic Victoria, Australia: Igneous rocks, ages and their interpretation. *J. geol. Soc. Aust.* 28: 395-421.

ROSENGREN, N., 1978. The physiography of coastal dunes, East Gippsland, Victoria. MA Thesis, Univ. Melb. (unpubl.).

TESSENSOHN, F., DUPHORN, K., JORDAN, H., KLEINSCHMIDT, G., SKINNER, D. N. B., VETTER, U., WRIGHT, T. O. & WYBORN, D., 1981. Geological comparison of basement units in Northern Victoria Land, Antarctica. *Geol. Jb.* B41: 31-88.

WALKER, R. G., 1978. Deep water sandstone facies and ancient submarine fans: models for exploration for stratigraphic traps. *Bull. Am. Assoc. Petrol. Geol.* 62: 932-966.

WALKER, R. G. & MUTTI, E., 1973. Turbidiate facies and facies associations. In *Turbidites and deep water sedimentation*, G. V. Middleton & A. H. Bouma, eds. *Soc. Econ. Paleontol. Mineral.* (Pacific Section) Short Course, Anaheim, California, 119-157.

WEBBY, B. D., VANDENBERG, A. H. M., COOPER, R. A., BANKS, M. R., BURRETT, C. F., HENDERSON, R. A., CLARKSON, P. D., HUGHES, C. P., LAURIE, J., STAIT, B., THOMSON, M. R. A. & WEBERS, G. F., 1981. The Ordovician System in Australia, New Zealand and Antarctica. Correlation Chart and Explanatory Notes. *Inter. Union Geol. Sci. Publ.* 6: 1-64.

WILSON, C. J. L., HARRIS, L. B. & RICHARDS, A. L., 1982. Structure of the Mallacoota area, Victoria. *J. geol. Soc. Aust.* 29: 91-105.